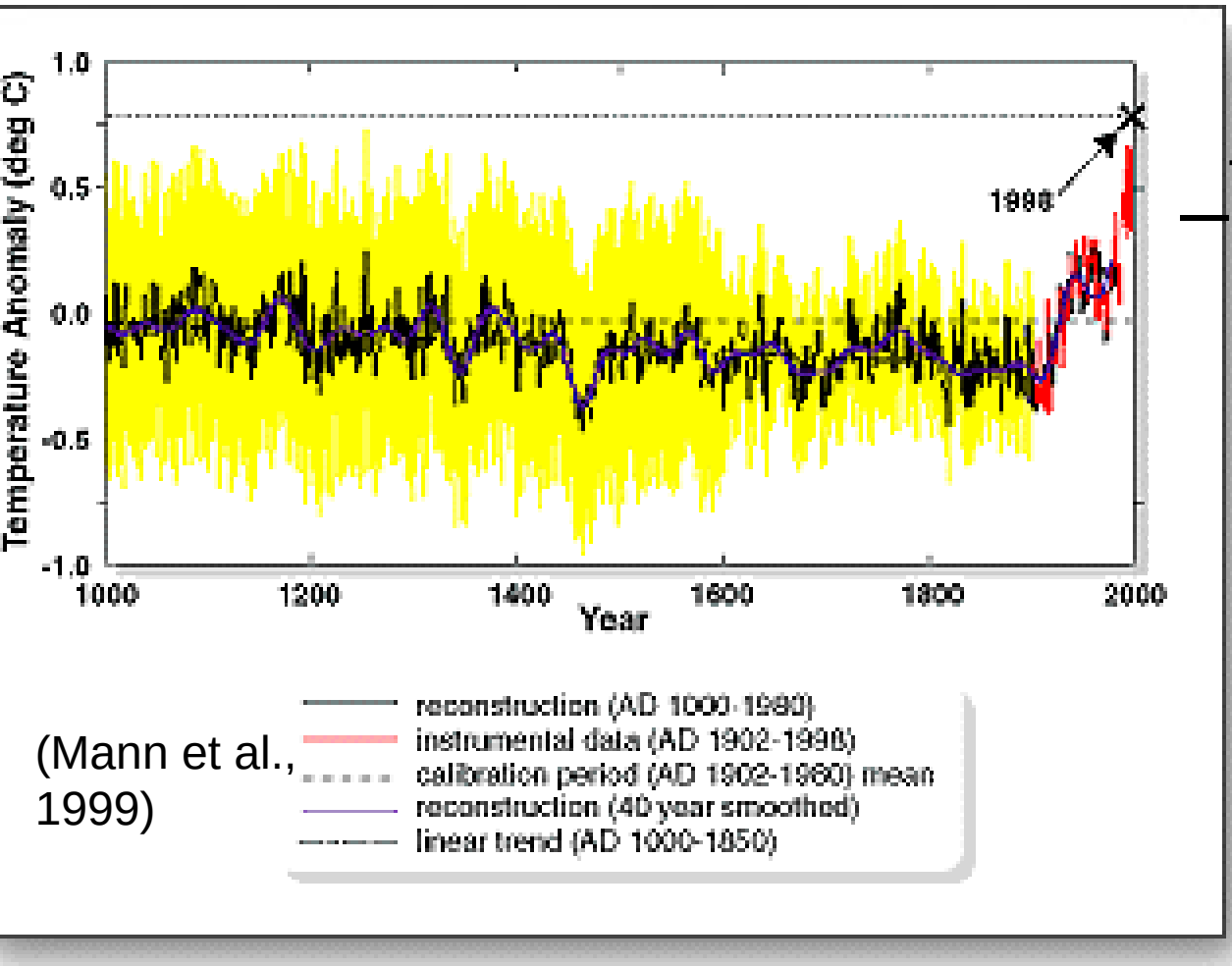
Holocene variability of Benguela upwelling

ODP's ***JOIDES Resolution***
http://www-odp.tamu.edu/

Christa Farmer
christa@LDEO.columbia.edu
Peter deMenocal
Tom Marchitto
Lamont-Doherty Earth Observatory

With thanks to: DOE/ORAU/GREF, LDEO Climate Center, ODP, Jean Lynch-Stieglitz, Martin Visbeck, Tom Guilderson, Tom Koutavas, Sarah Ingram, Martha Bryan, Linda Baker, Pat Malone, Grace Kim, and so many other helpful folks...

Why do we care about millennial climate change?



(Mann et al., 1999)

To understan
historical
climate chan
(red),

we need to
understand
“natural”
geological
climate chan
(yellow)

tropical Atlantic climate change over the last 20,000 years

- Greenland ice cores show little Holocene climate variability

(Dansgaard, 1993)

- global marine records suggest Little Ice Age is part of a persistent pattern:
  - how widespread is it ?
  - origin in tropics? high-latitudes?
  - S Hem same timing as N Hem?

(Bond, 2001; deMenocal 2000

timing of deglacial climate change between hemispheres:

N Hem deglaciation cold interval

"Younger Dryas" (11.5-13 kyr BP)

lags comparable event in S Hem

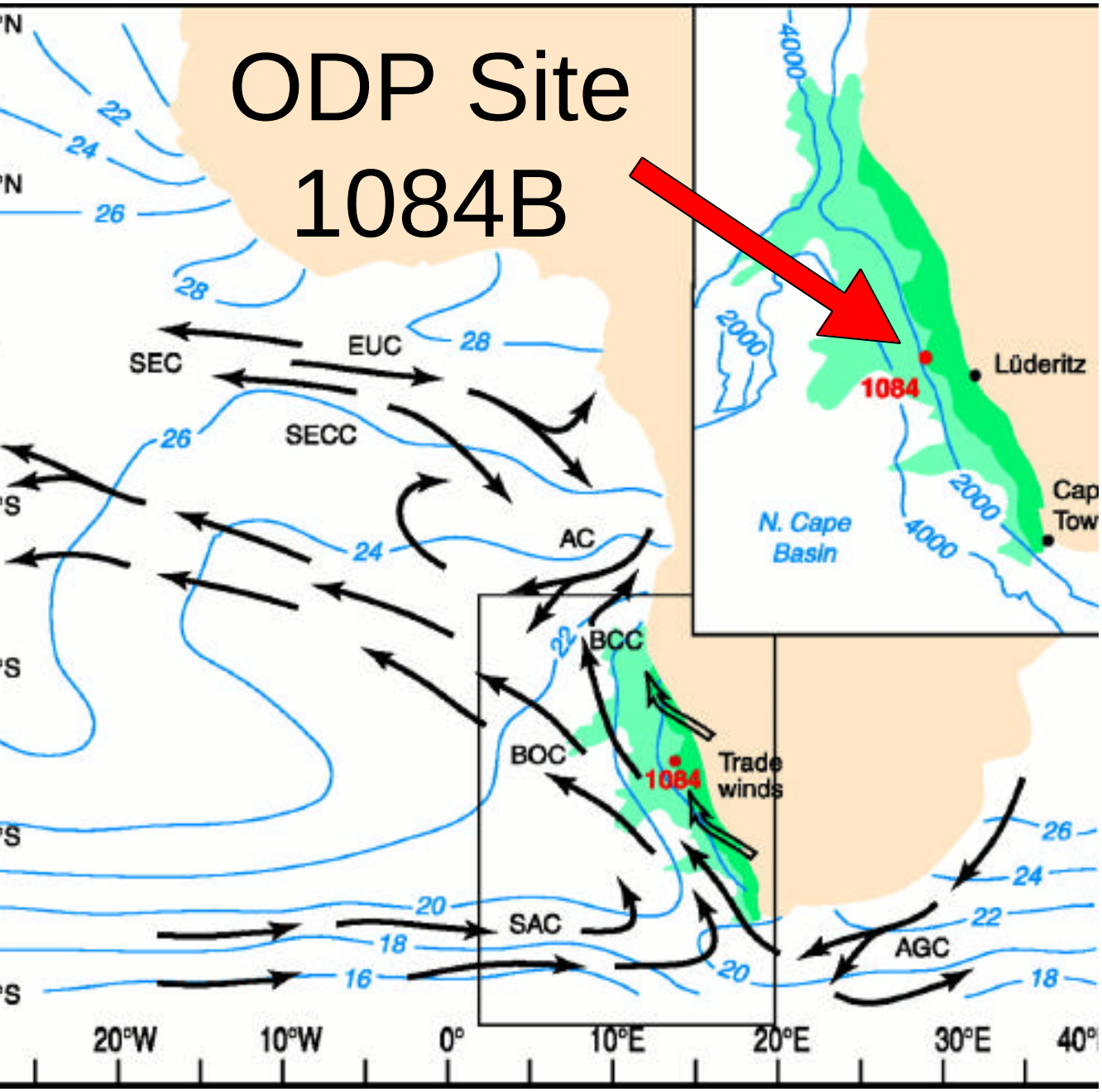
Blunier et al., 1998)

- N Hem deglacial lag interval confirmed:

  ~ 1500 yrs

(Charles et al., 1996)

✸S Hem subtropics match ***N Hem*** polar regions in deglacial timing!



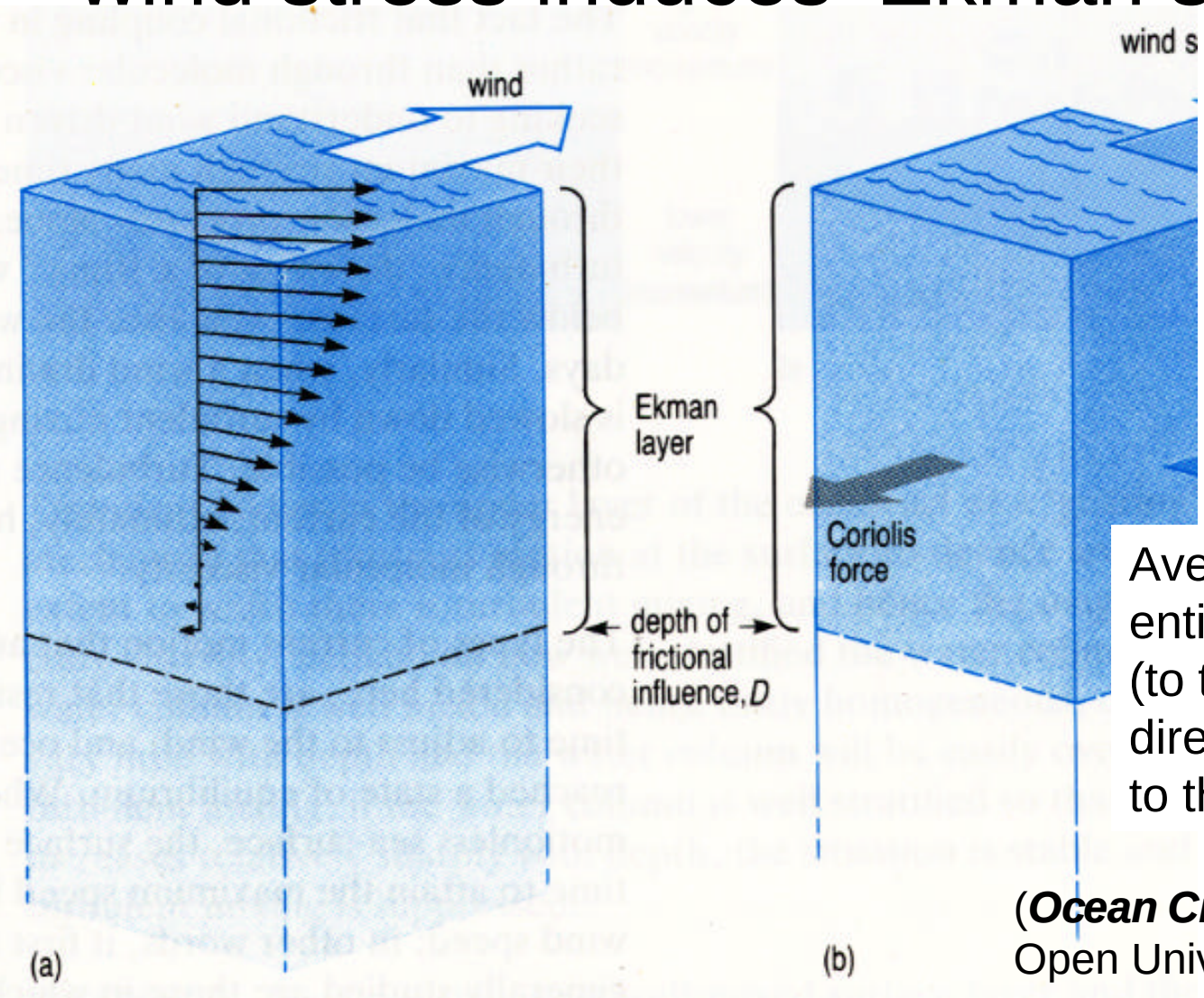
Benguela upwelling zone off Namibia

near where Indian Ocea water mixes with waters from South Atlantic

2000m wat depth on continental shelf

(Marlow et a 2000, Scien

physics of upwelling (in 5 min or less): wind stress induces ‘Ekman spiral’



Average motion
entire Ekman lay
(to the right of w
direction in N He
to the left in S H

(***Ocean Circulation***,
Open University, p. 36)

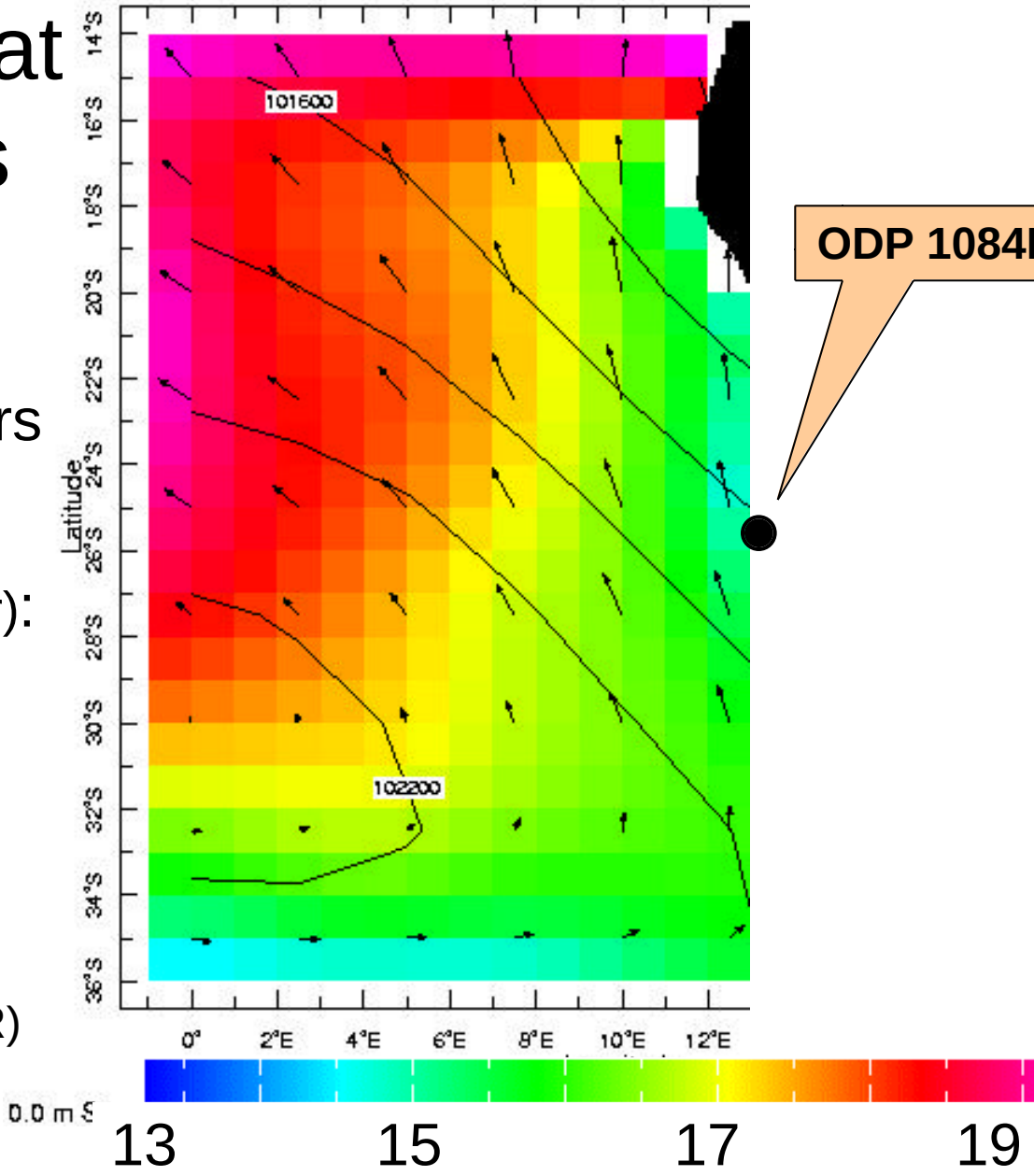
Divergence at coast gives upwelling:

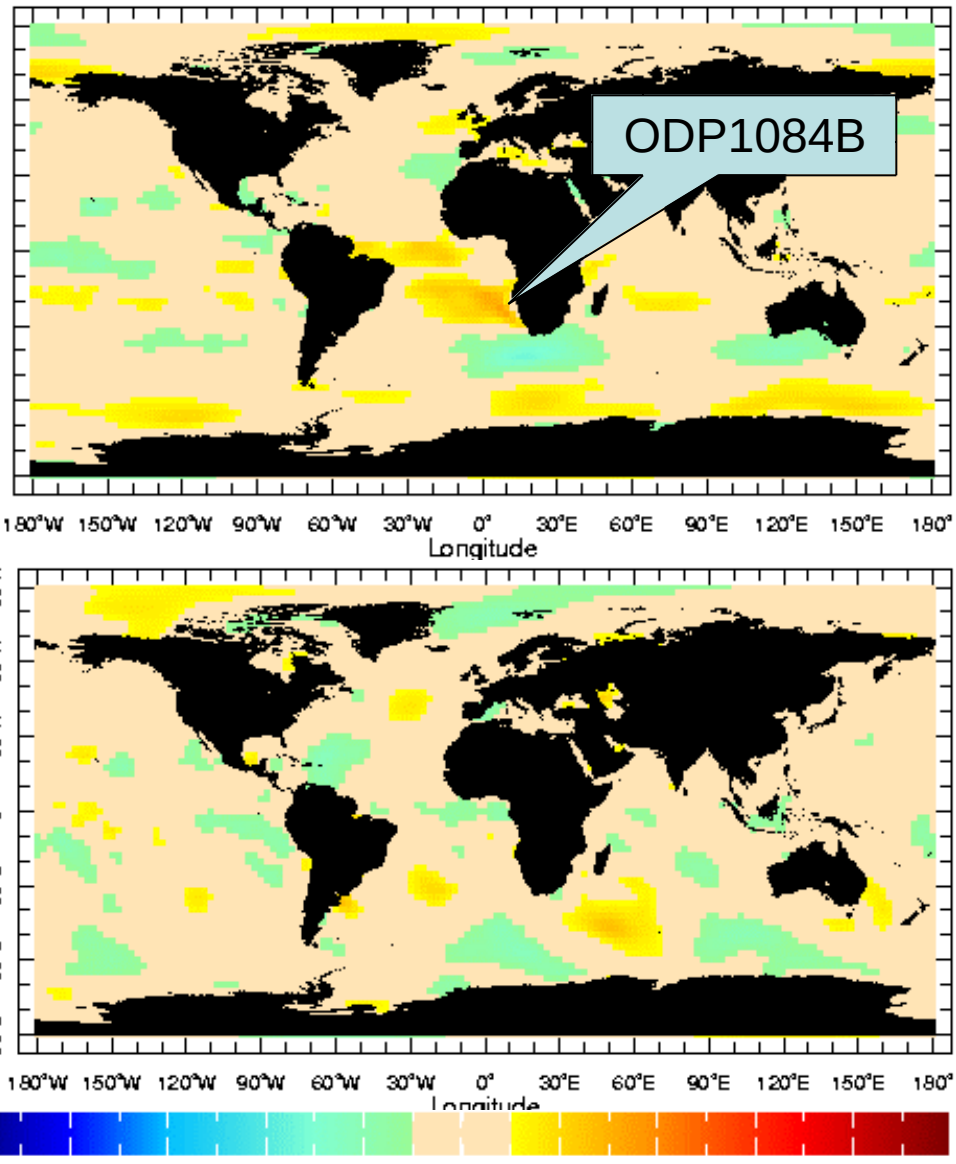
deep, colder waters rise to surface along coast

Feb (S Hem summer): least upwelling, SST=17.2 °C

Sep (S Hem winter): most upwelling, SST=14.8 °C

OAA WOA, NCEP-NCAR)





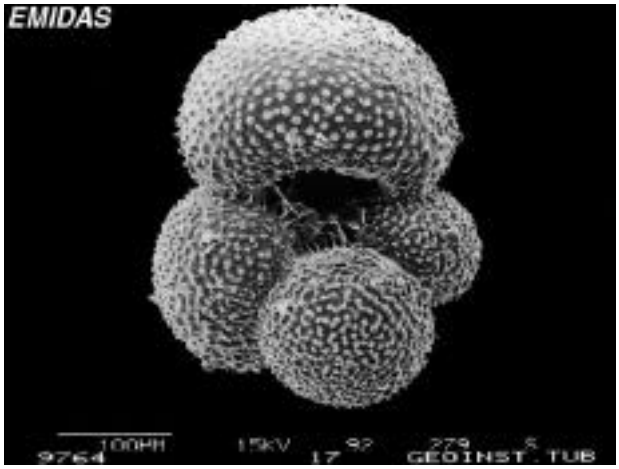
correlations with global wind strength:

- monthly anomaly SST at site ODP1084B
- highest for local zonal wind strengt

15-20 % of variance

(NOAA WOA, NCEP-NCAR

G. bulloides: planktic foraminifera



- protozoa that live in and above oceanic thermocline

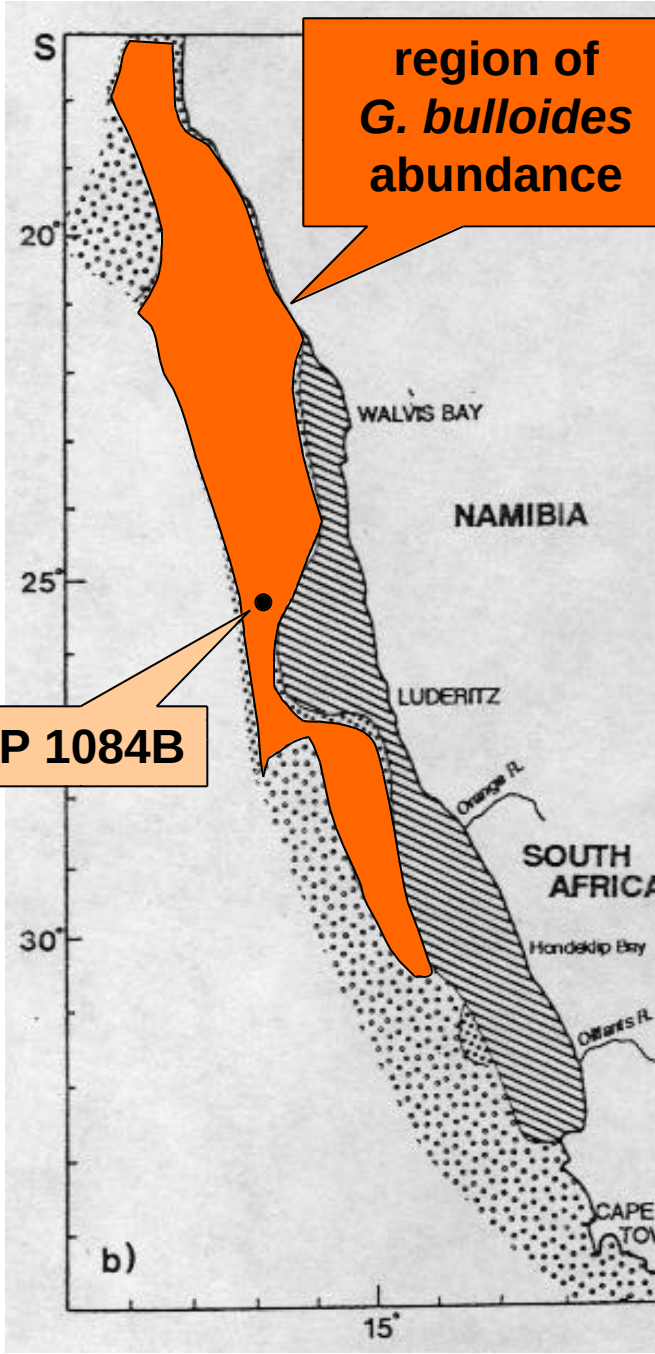
  (upper ~400m)
- transitional to polar locations, upwelling environments
- $CaCO_3$ skeleton provides temperature, global ice volume, faunal abundance, and other proxies

***G. bulloides*:** upwelling indicator

Intermediate between species that prefer colder and warmer waters

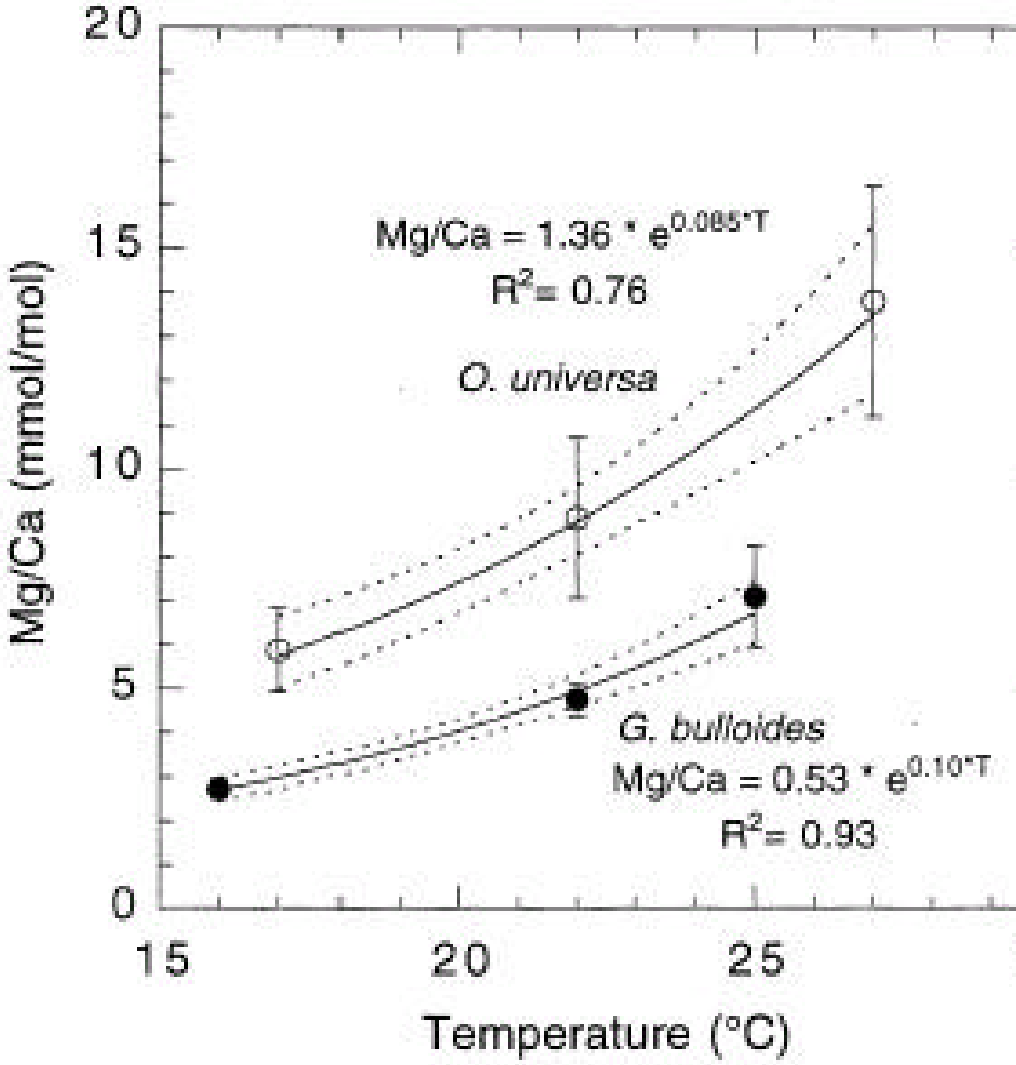
Faunal abundance data suggests movement of front?

(Giraudeau & Rogers, 1994)

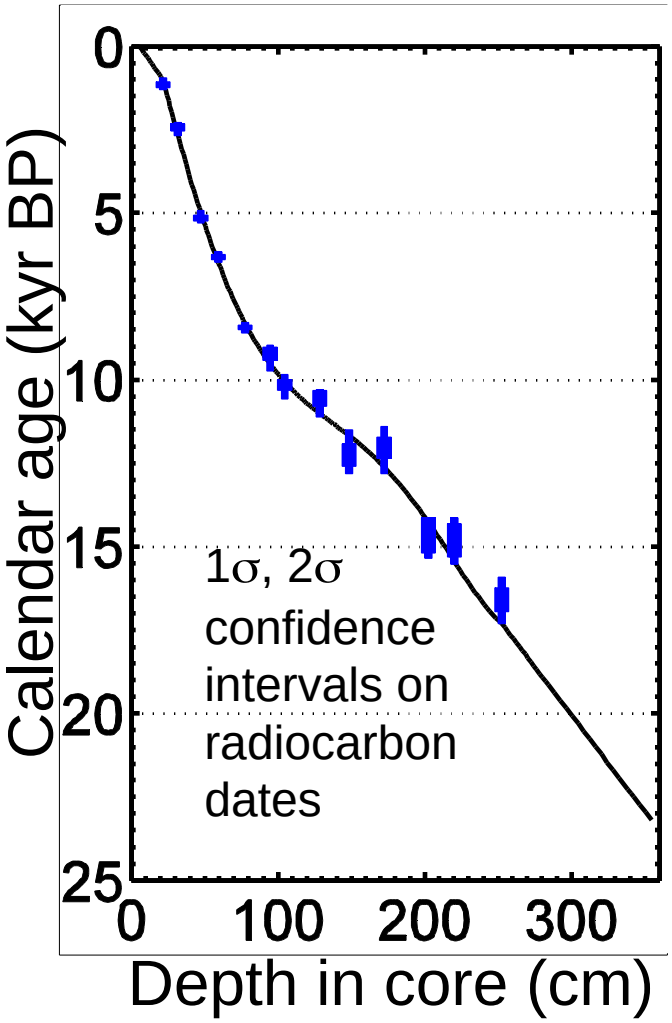


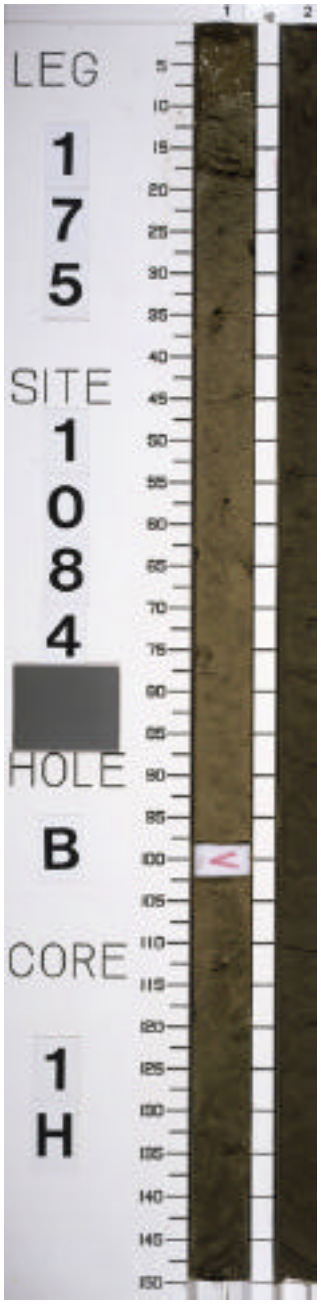
***G. bulloides*: temperature proxy**

- Lea et al. 1999 growth experiments
- [Mg]/[Ca] of ***G. bulloides*** depends on temperature

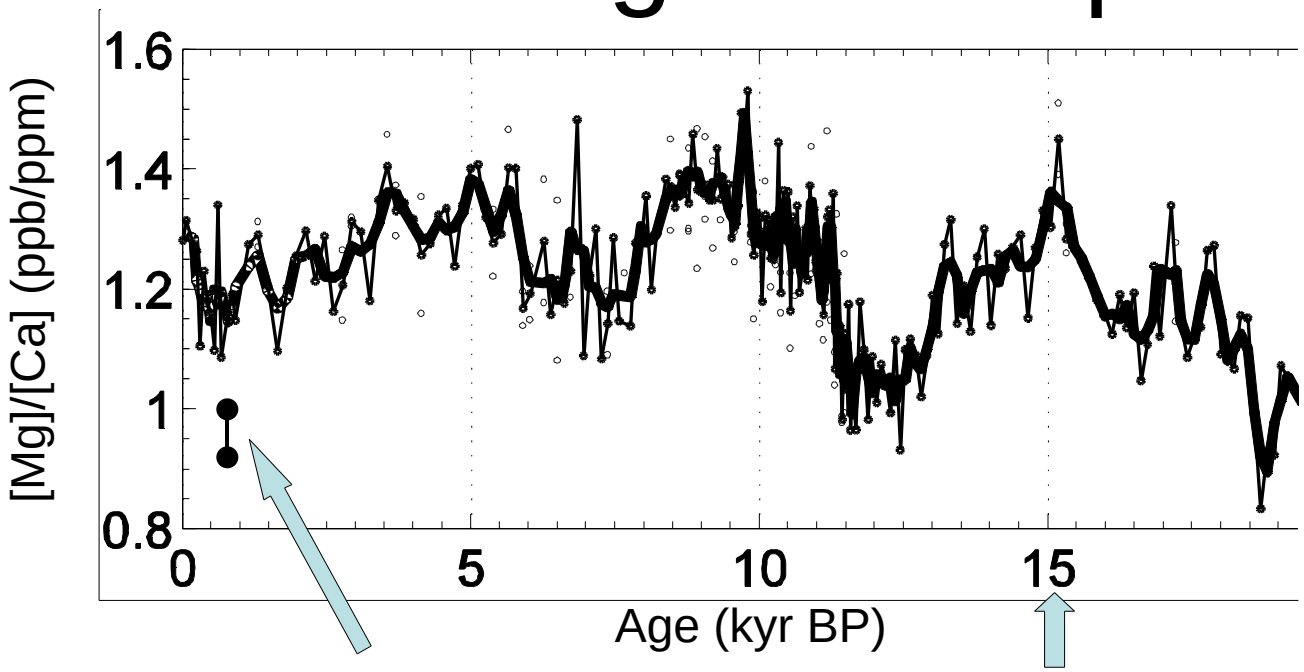


^{14}C Age model for core 1084B:



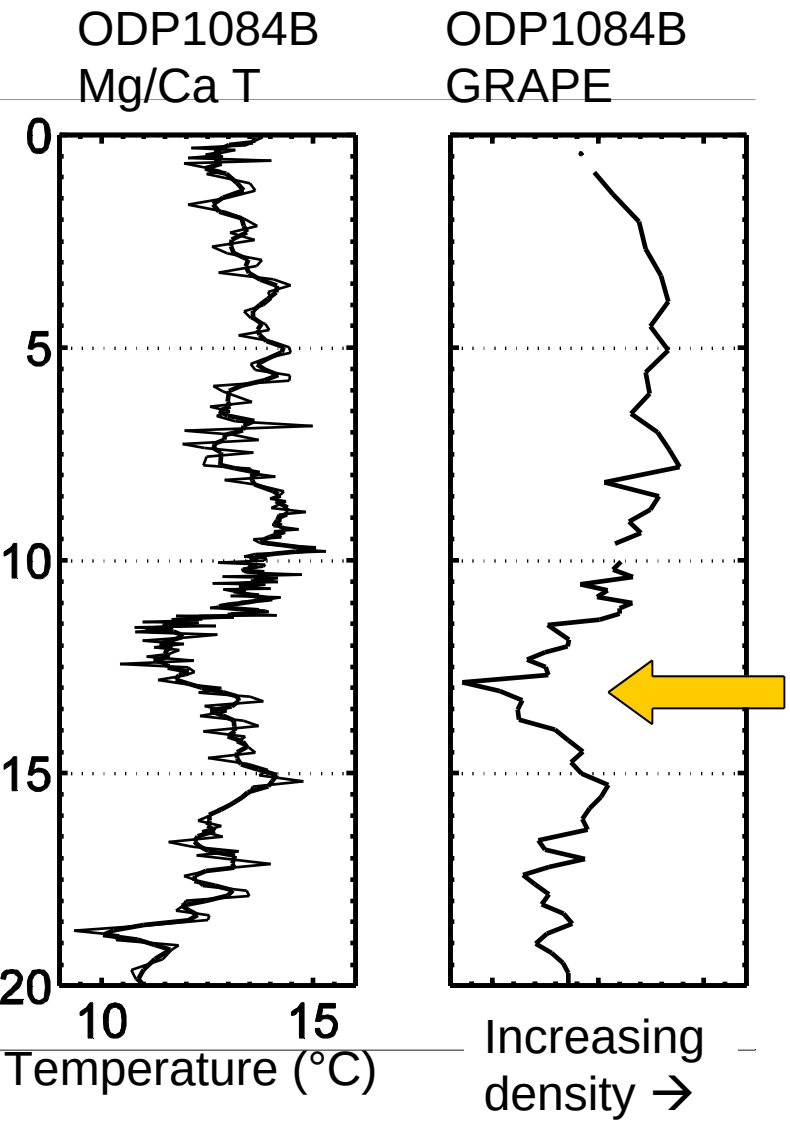


Results: Mg/Ca temperature



- average difference between replicates: 0.08 (ppb/ppm)
- coretop value (1.3=13.6°C) matches modern winter (14.8°C) within confidence limits of Lea 1999 regression (+/-1.1°C)
- age model below ~15k yBP i not reliable: more dates neec
- wind strength fluctuation changes temperature, but ho much is also due to changes ocean currents? →further wo

MST GRAPE data:

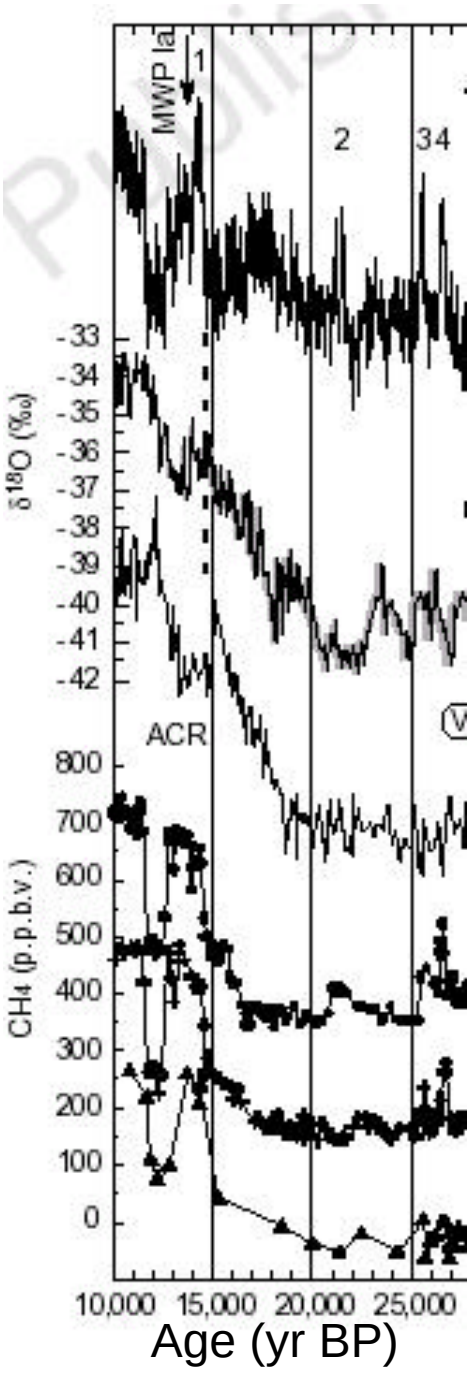


- Gamma Ray Attenuation inversely proportional to sediment density
- sharp density change at beginning of Younger Dryas (11,500-13,000 yr BP

Deglacial timing between hemispheres:

- N Hem:“Younger Dryas” cold period between glacial maximum and Holocene
- S Hem: “Antarctic Cold Reversal” precedes YD by ~1500 yrs, meltwater pulse by ~1000 yrs

(Blunier et al., 1998)



N Hem
GRIP

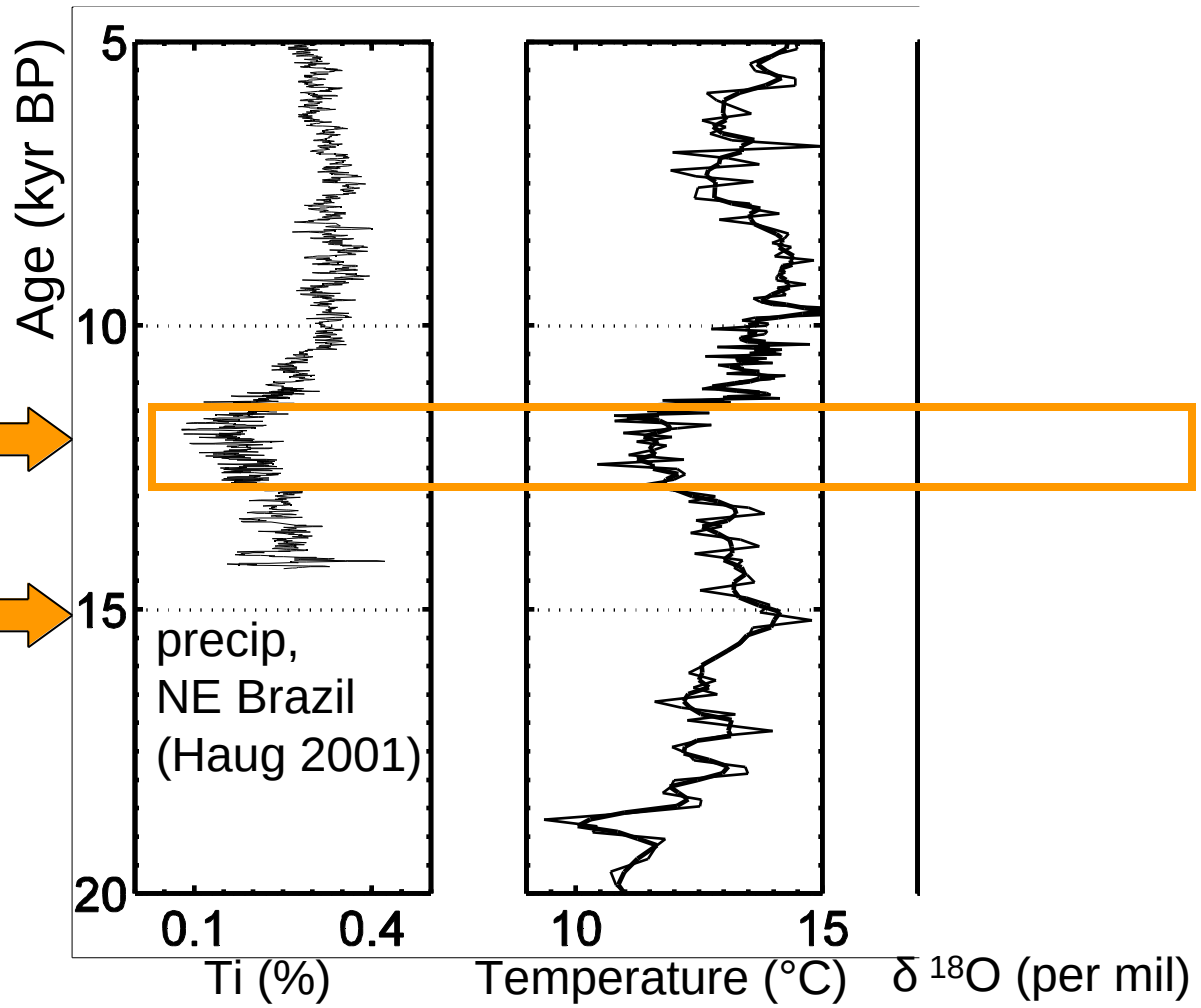
S Hem
Byrd &
Vostol

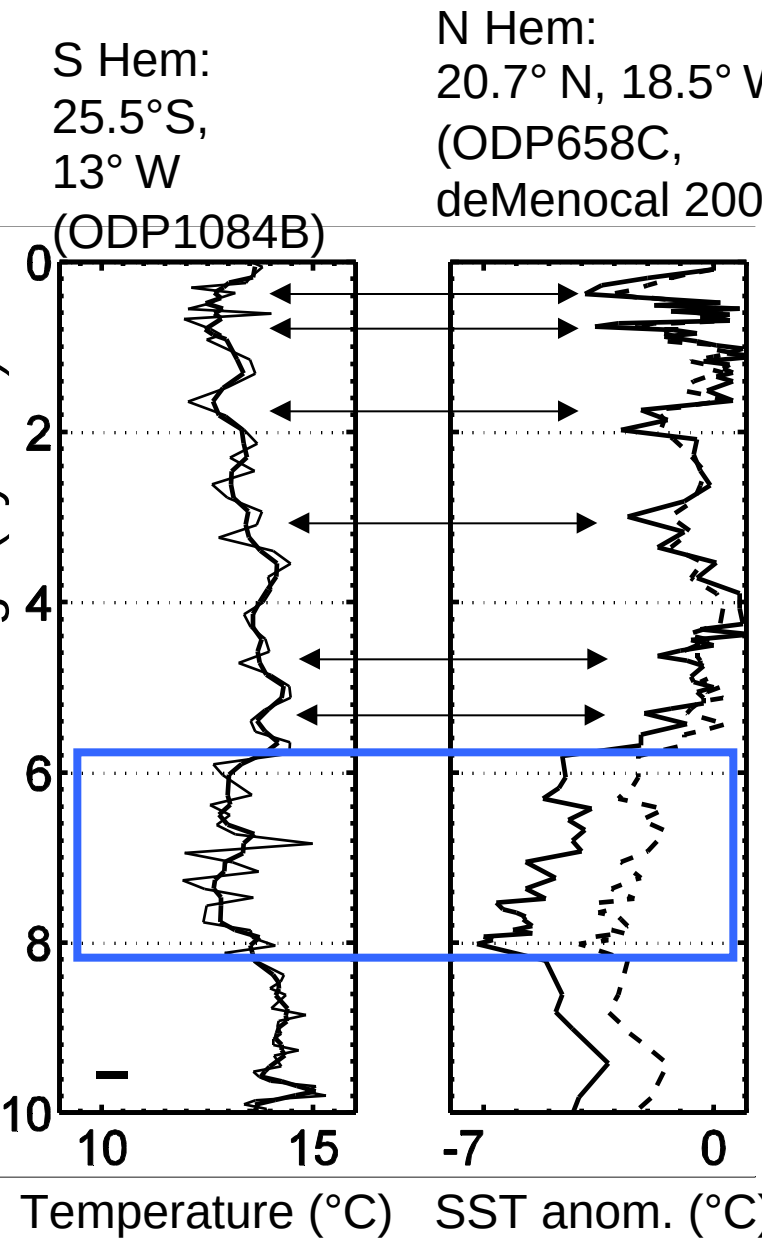
commo
timesca

Younger Dryas:

1084B matches N Hem records

S Hem ACR started 15kyr BP





Holocene:

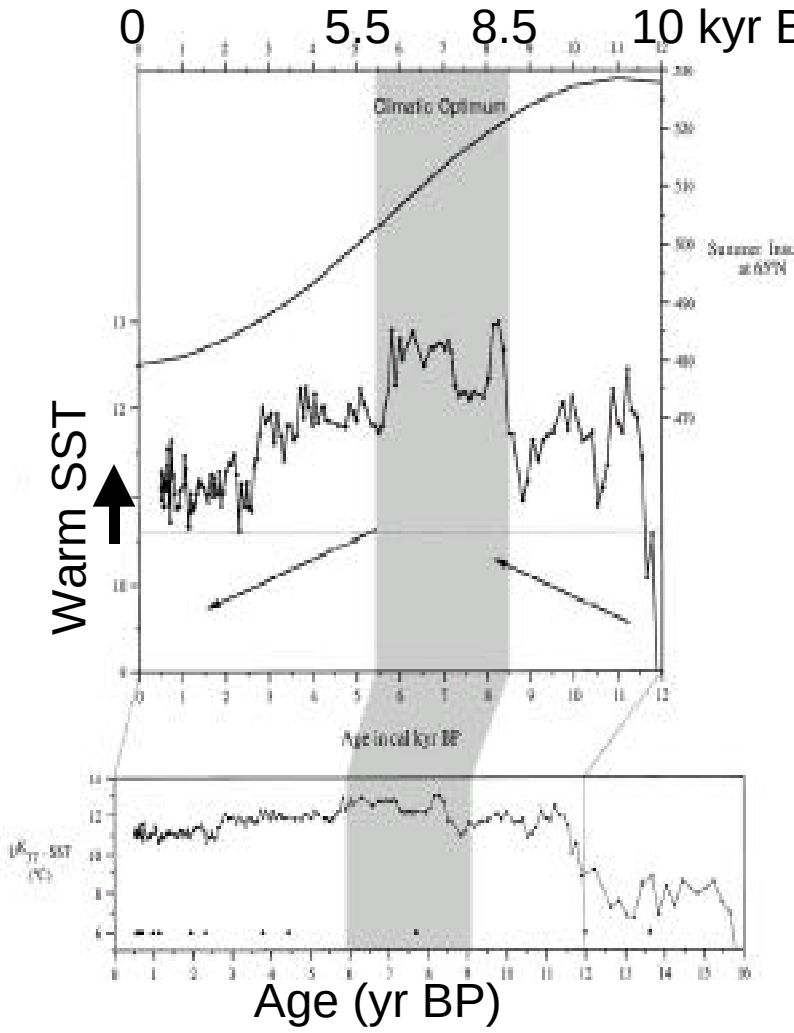
- both hemispheres have same timing for subtropical Atlantic cooling events ~8kyrBP & 6.5kyrBP
- other millennial events seem to match too, but resolution too poor to say for sure

mid-Holocene: 1084B cooling while N Atlantic warming

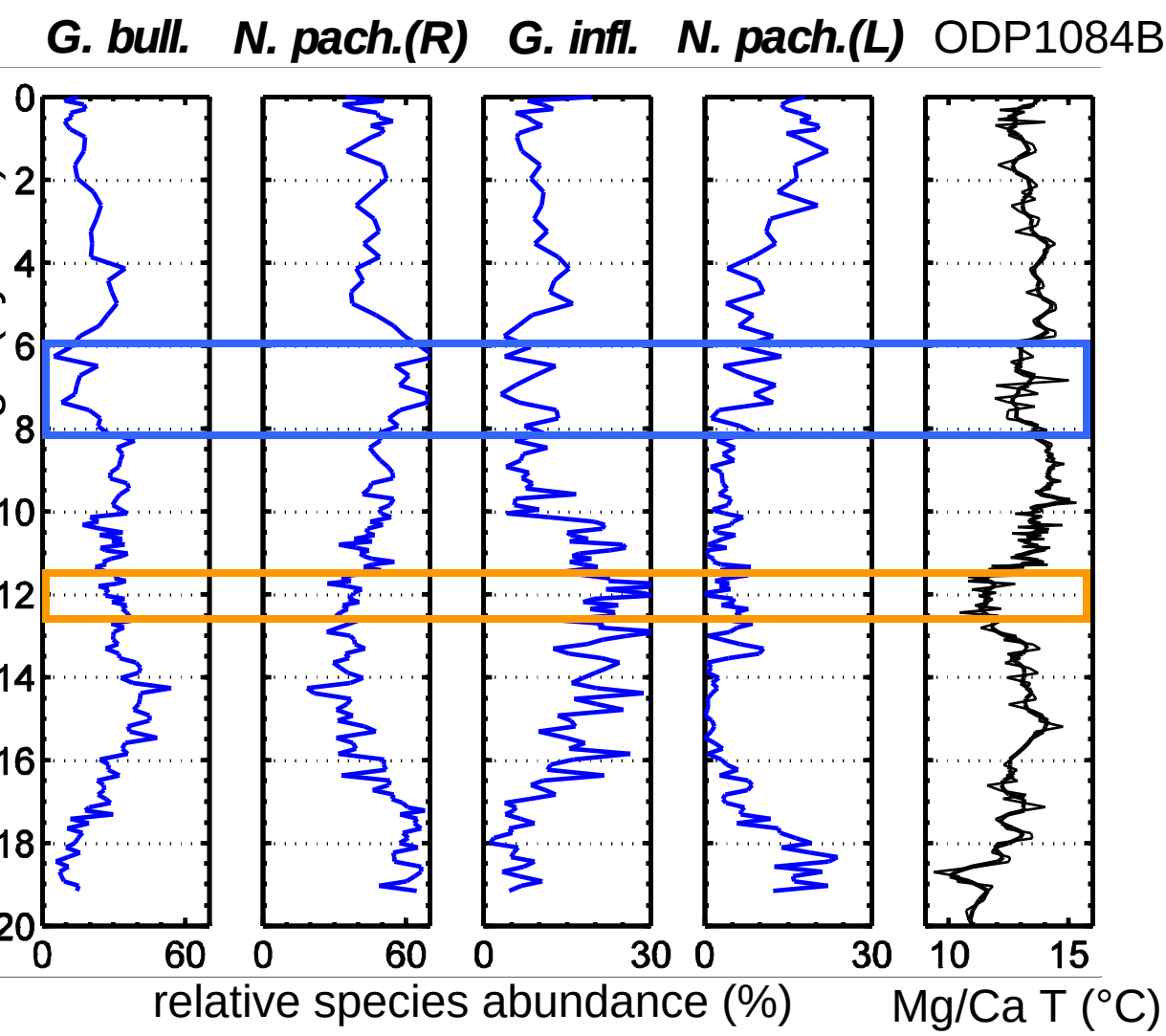
Norwegian Sea (65N) warms while Benguela upwelling region is cooling

Why is site 1084B in phase with subpolar N Hem for Younger Dryas but not 5.5-8.5kyr BP?

(Calvo et al., 2002)



Faunal abundance results

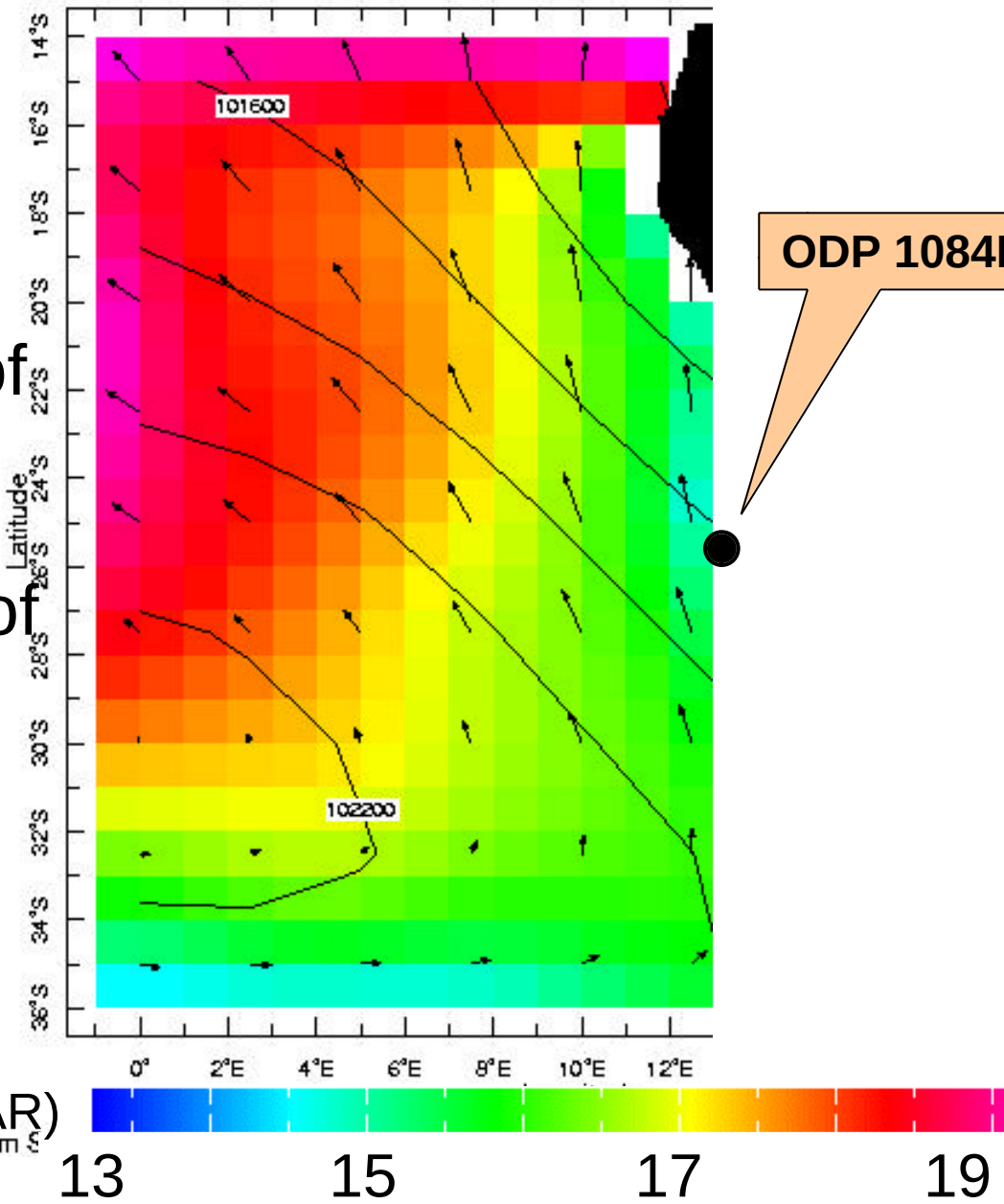


- intriguing possibilitie for faunal proxies...

Faunal indicators:

[(L/B)]:
W-E extension of upwelling cells?

[(B+R)/(I+L)]:
N-S movement of oceanic front?
Change in intensity of “thermohaline circulation”?



NOAA WOA, NCEP-NCAR)

Faunal indicators:

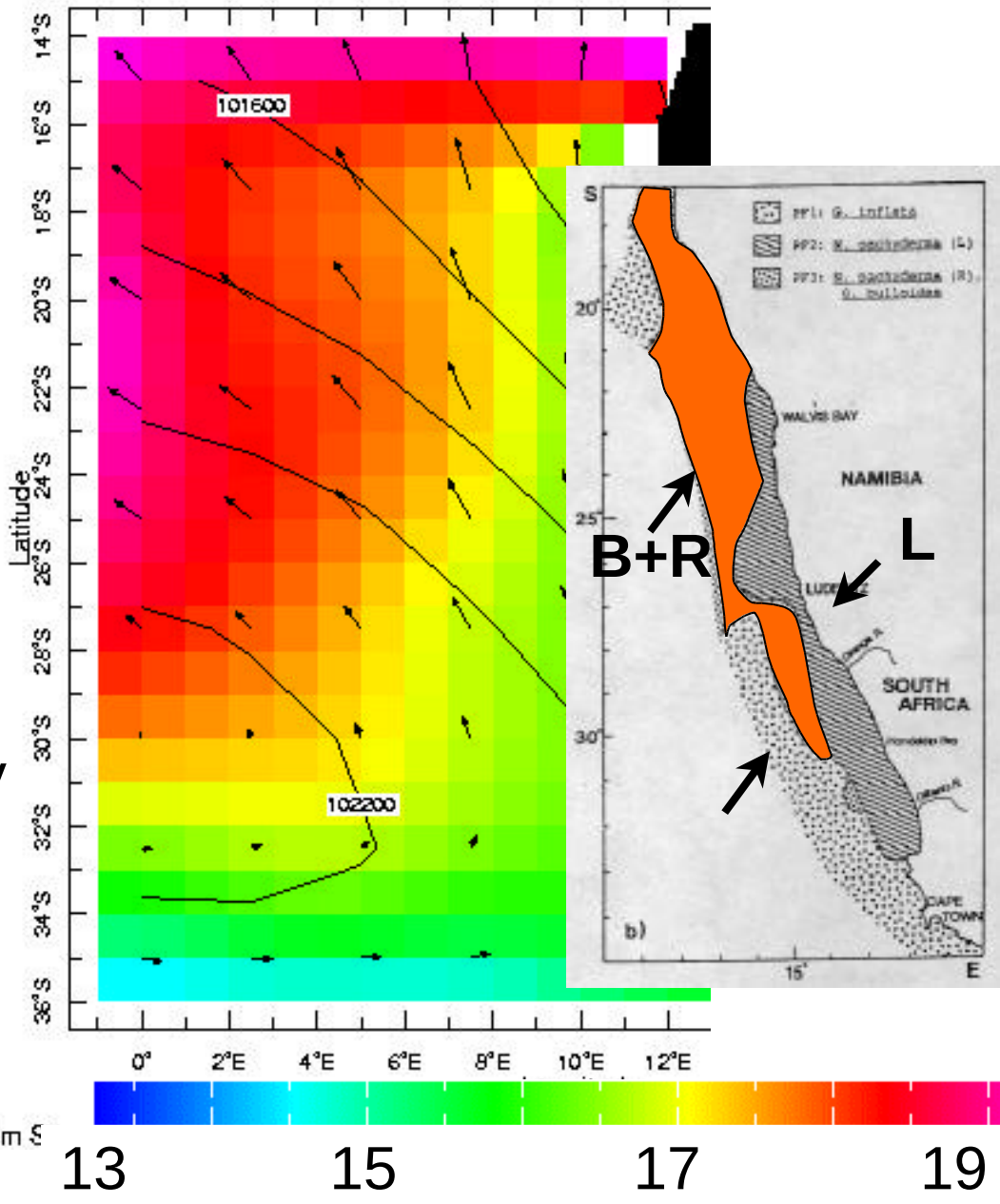
[(L/B)]:

W-E extension of upwelling cells?

[(B+R)/(I+L)]:

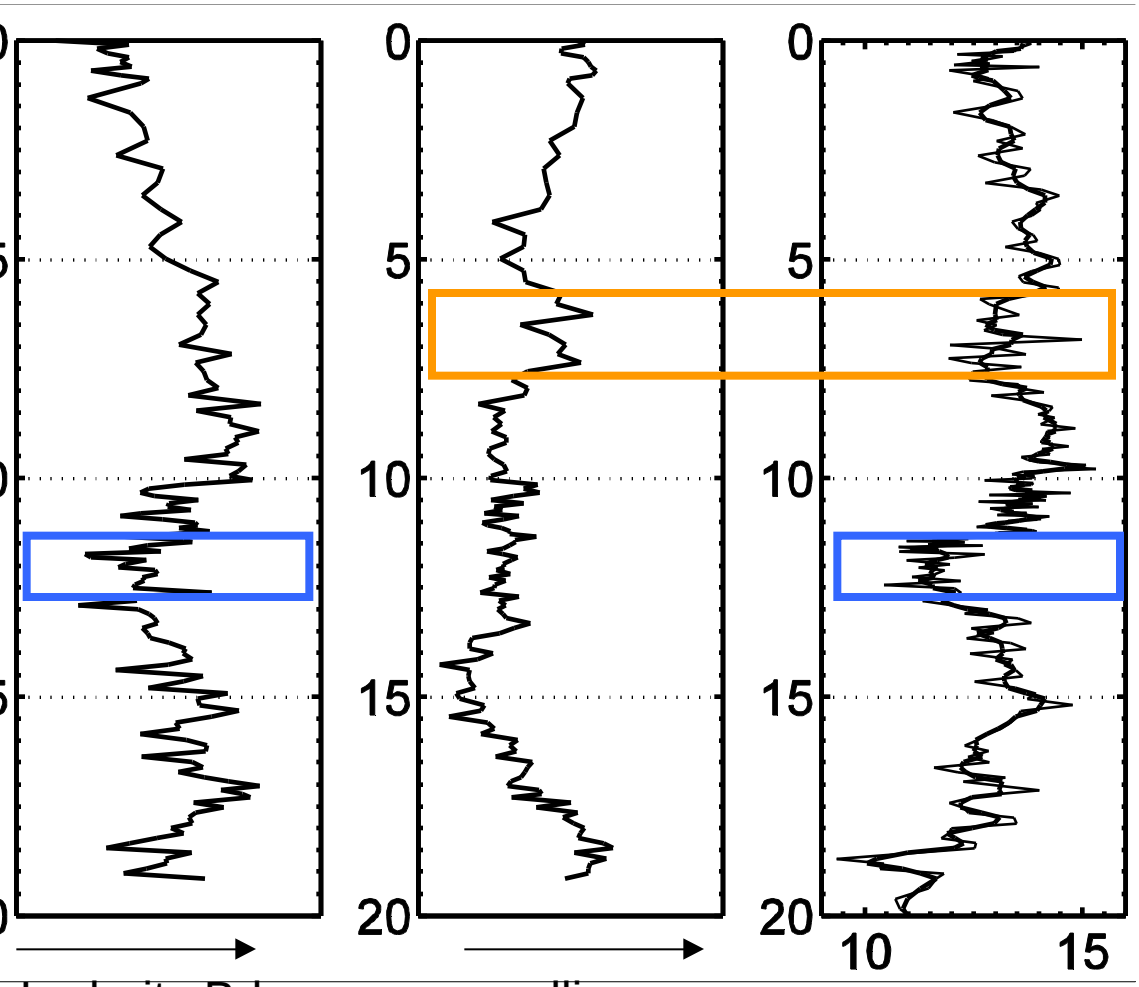
N-S movement of oceanic front?

Change in intensity of “thermohaline circulation”?



NOAA WOA, NCEP-NCAR)

Why Hem phasing is different for two major climate events in ODP1084B:



- perhaps Holocene event is caused by changing wind strength

→Hems in phase

- while Younger Dryas is caused by changing ocean circulation

→Hems outof phase

Conclusions:

S Hem subtropics:

- match N Hem deglacial timing, not S Hem
- match N Hem subtropical mid-Holocene cooling events, but opposite of warming in subpolar N Atlantic

→resolution in this core not quite high enough to show millennial variability

Further Work:

- more ^{14}C dates from lower section
- ^{15}N, upwelling proxy

→future coring cruise is planned: hopefully it will get better sediments!!


Thanks!